

## **COAXIAL CABLE JUMPER ASSEMBLY INCLUDING PLATED OUTER CONDUCTOR AND ASSOCIATED METHODS**

### **Field of the Invention**

The present invention relates to the field of communications, and, more particularly, to a coaxial cable jumper assembly and related methods.

### **Background of the Invention**

5 Coaxial cables are widely used to carry high frequency electrical signals. Coaxial cables enjoy a relatively high bandwidth, low signal losses, are mechanically robust, and are relatively low cost. A  
10 coaxial cable typically includes an elongate inner conductor, a tubular outer conductor, and dielectric separating the inner and outer conductors. For example, the dielectric may be a plastic foam material. An outer insulating jacket may also be applied to surround the  
15 outer conductor.

One particularly advantageous use of coaxial cable is for connecting electronics at a cellular or wireless base station to an antenna mounted at the top of a nearby antenna tower. For example, the transmitter and receiver  
20 located in an equipment shelter may be coupled via coaxial cables to antennas carried by the antenna tower. A typical installation includes a relatively large

diameter main coaxial cable extending between the equipment shelter and the top of the antenna tower to thereby reduce signal losses. For example, CommScope, Inc. of Hickory, North Carolina and the assignee of the  
5 present invention offers its CellReach® coaxial cable for such applications.

Each end of the main coaxial cable may be coupled to a smaller diameter, and relatively short, coaxial cable jumper assembly. The coaxial cable jumper assembly  
10 includes a length of coaxial cable with connectors attached to the opposing ends. The cable of the jumper cable assembly is typically of a smaller diameter than the main coaxial cable to provide a smaller cross-section, greater flexibility and facilitate routing at  
15 the equipment shelter, and also at the top of the antenna tower, for example. Connectors are typically coupled to each end of the jumper coaxial cable to form the coaxial cable jumper assembly.

A coaxial cable is typically manufactured in a  
20 continuous fashion wherein an inner conductor or wire and is advanced along a path through an extruder which extrudes a dielectric foam around the inner conductor. Downstream from the extruder are a series of cooling tanks to cool and solidify the dielectric foam. The outer  
25 conductor may be applied as a metallic tape formed into a tube around the dielectric layer. The plastic insulating jacket may be extruded downstream from application of the outer conductor.

The connectors for the jumper cable assembly can be  
30 installed onto the ends of the coaxial cable at the cable manufacturing plant and/or in the field. Connectors are available in two main categories - mechanical-type

connectors which are configured for mechanical installation onto the end of the jumper coaxial cable, and solder-type connectors which are configured to be coupled by soldering. Unfortunately, the mechanical-type  
5 connector is relatively complicated, includes many parts, and, therefore, is relatively expensive. Solder-type connectors may be less expensive because of fewer parts. For example, U.S. Patent No. 5,802,710 to Bufanda et al. discloses a solder-type connector which uses a solder  
10 perform wrapped around an annularly corrugated outer conductor of the coaxial cable. The connector body is placed over the solder perform and then heated to solder the connector to the end of the cable.

Unfortunately, not all materials used in connectors  
15 and/or coaxial cables are readily suited to soldering. Aluminum is a highly desirable material and is often used for the outer conductor of a jumper coaxial cable. Unfortunately, aluminum does not readily accept solder, and, therefore, more expensive mechanical-type connectors  
20 have typically been used in combination with a jumper coaxial cable having an aluminum outer conductor.

#### Summary of the Invention

In view of the foregoing background, it is therefore an object of the present invention to provide a coaxial  
25 cable jumper assembly that is rugged and readily manufactured, that includes aluminum as the outer conductor material, and which includes at least one solder-type connector.

This and other objects, features, and advantages in  
30 accordance with the present invention are provided by a jumper assembly comprising a jumper coaxial cable

including an outer conductor, which, in turn, comprises aluminum with a tin layer thereon, and wherein at least one connector is soldered to the tin layer. More particularly, the jumper coaxial cable may be of  
5 relatively short length and include an inner conductor, a dielectric layer surrounding the inner conductor, the outer conductor surrounding the dielectric layer, and an outer jacket surrounding the outer conductor. The tin layer may be a tin alloy, such as a tin/lead alloy, for  
10 example. Advantageously, the tin layer permits an aluminum conductor to be used, yet facilitates soldering of a solder-type connector onto the outer conductor.

The outer conductor may have a continuous, non-braided, tubular shape. The tin layer may extend  
15 continuously along an entire length of the outer conductor, and be on a radially-outer surface of the aluminum layer, for example. The tin layer may be readily formed by plating during manufacturing of the jumper coaxial cable.

20 The jumper cable assembly may include first and second connectors on opposing first and second ends of the jumper coaxial cable. The jumper coaxial cable may have characteristics to be shape-retaining when formed into a shape having at least one bend therein. This  
25 shape-retaining quality may be especially advantageous when routing the jumper assembly to rack-mounted electronic equipment, such as a transmitter or receiver.

The inner conductor may comprise an aluminum rod with a copper layer thereon. The connector may further  
30 comprise a connector contact coupled to the inner conductor. The dielectric layer may include plastic, such as a plastic foam, for example. In addition, the

jumper coaxial cable may have a diameter in a range of about 1/8 to 2 inches.

Another aspect of the invention relates to a coaxial cable system including a main coaxial cable and a coaxial cable jumper assembly, including the tin-plated outer conductor, and connected to one or both ends of the main cable. The main coaxial cable may have a larger diameter than the coaxial cable of the jumper assembly to thereby reduce signal attenuation. The smaller cable of the jumper assembly may be more flexible and shape retaining which would allow tighter bends required in many routing applications.

Yet another aspect of the invention is directed to a method for making the coaxial cable jumper assembly as described above. The method may include forming a tin layer on an aluminum outer conductor of a jumper coaxial cable comprising an inner conductor and a dielectric layer between the inner and outer conductors; and soldering at least one connector to the tin layer adjacent at least one respective end of the jumper coaxial cable. The tin layer may be a tin alloy, such as a tin/lead alloy, for example, as noted above. The outer conductor may have a continuous, non-braided, tubular shape, and the tin layer may be formed by plating.

#### Brief Description of the Drawings

FIG. 1 is a schematic diagram of a cellular base station illustrating a coaxial cable system including the coaxial cable jumper assembly in accordance with the present invention.

FIG. 2 is a side elevational view of a portion of the coaxial cable system as shown in FIG. 1.

FIG. 3 is a greatly enlarged schematic transverse cross-section view take along lines 3-3 of FIG. 2.

FIG. 4 is a greatly enlarged schematic longitudinal cross-sectional view taken along lines 4-4 of FIG. 2.

5        FIGS. 5 and 6 are more detailed perspective and top plan views, respectively, of a solder-type connector as included with the coaxial cable jumper assembly as shown in FIG. 1.

FIG. 7 is a schematic block diagram of an apparatus  
10    for making the coaxial cable jumper assembly in accordance with the invention.

FIG. 8 is a flow chart for the method of making the coaxial cable jumper assembly in accordance with the invention.

15        **Detailed Description of the Preferred Embodiments**

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in  
20    many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like  
25    numbers refer to like elements throughout.

Turning initially to FIG. 1, a coaxial cable system in accordance with the present invention is described with reference to use in a cellular or wireless base station 10. The base station 10 illustratively includes  
30    an equipment shelter 11 which contains an equipment rack 12 which, in turn, mounts a plurality of transmitters 13

and receivers 14. A cable tray 15 illustratively extends outside of the equipment shelter 11 to a monopole tower 16. The monopole tower 16 mounts a plurality of cellular antennas 17 at its upper end as will be appreciated by those skilled in the art.

As will also be appreciated by those skilled in the art, the coaxial cable system establishes connections between the antennas 17 at the top of the tower 16 and the transmitters 13 and receivers 14 located at the bottom of the tower and within the shelter 11. The coaxial cable system illustratively includes a plurality of coaxial cable jumper assemblies 20 connected to larger main coaxial cables 21 which run from the upper end of the tower 16 into the equipment shelter 11. The main cables 21 may each be a CellReach® model 1873 cable, for example, having a relatively large diameter (about 1 and 5/8 inch) and which typically extend about 90 to 300 feet.

In the illustrated embodiment, jumper assemblies 20 are used at both the upper and lower locations, and the main coaxial cables 21 run within the monopole tower 16. Of course, in other embodiments, only a single jumper assembly 20 may be used, although typically the flexibility of the jumper assembly makes it advantageous to use at both the upper and lower locations.

Turning now additionally to FIGS. 2 and 3, specific features of the jumper cable assembly 20 are now described. This coaxial cable jumper assembly 20 may typically be about 3 to 6 feet long. The jumper assembly 20 illustratively includes a jumper coaxial cable 25 which, in turn, includes an inner conductor 26 provided by an aluminum wire 27 with copper cladding 28 thereon.

Other configurations of inner conductor are also contemplated by the present invention.

The inner conductor 26 is surrounded by a foam dielectric layer 30. The dielectric layer 30 is  
5 surrounded by an outer conductor 32. The outer conductor 32 is illustratively provided by an aluminum tube 33 with a tin layer 34 thereon. The tin layer 34 advantageously provides a highly compatible surface for soldering. Of course, as used herein "tin layer" is meant to include a  
10 pure or substantially pure tin layer, as well as tin alloys, such as tin/lead alloys, for example. In particular, a tin/lead alloy including about 10 percent lead may be used. In other words, the disadvantage of an aluminum outer conductor is overcome by providing a tin  
15 layer 34 on the aluminum tube 33 of the outer conductor 32. As will be appreciated by those skilled in the art, aluminum provides a number of desirable other properties including good conductivity, shape-retaining properties, durability, relatively low yield strength, and relatively  
20 low cost. External to the outer conductor 32, a jacket or outer protective plastic layer 36 is illustratively provided.

The coaxial cable jumper assembly 20 also illustratively includes solder-type connectors 40 at both  
25 ends as perhaps best shown in FIG. 2. Of course, in other embodiments only a single solder-type connector 40 may be provided. In other words, the term "coaxial cable jumper assembly" as used herein is meant to cover embodiments including one or two connectors. For example, a pigtail  
30 version of the jumper assembly may include only one solder-type connector installed at the factory. A mechanical-type connector could then be installed in the



field, so that the length of the jumper coaxial cable 25 can be precisely measured and cut as will be appreciated by those skilled in the art.

For user convenience, it is envisioned that jumper assemblies 20 with two solder-type connectors 40 will be offered in a number of standard lengths. Accordingly, in these embodiments, the economy and efficiency of two solder-type connectors 40 can be enjoyed.

As mentioned briefly above, the materials and construction of the jumper coaxial cable 25 advantageously provide a shape-retaining property to the cable as perhaps also best understood with reference to FIGS. 1 and 2. In other words, relatively tight bends may be formed by hand, and, moreover, these bends will retain their shape upon release. This advantageous feature may make routing of the jumper assembly 20 considerably easier for the installer.

Referring now additionally to FIGS. 4-6, additional details of the solder-type connector 40 and its solder coupling to the jumper coaxial cable 25 are now described. The connector 40 illustratively includes a first tubular body portion 41 which receives the outer conductor 32 of the jumper coaxial cable 25. A second tubular body portion 42 is illustratively connected to the first body portion 41 such as provided by a tight press fit. A rotatable nut portion 43 (FIGS. 5 and 6) is carried by the second body portion 42.

A conductive contact 45 is carried within the second body portion 42 by a dielectric spacer disk, not shown. The conductive contact 45 is illustratively soldered onto the inner conductor 26 by a solder joint 47. This solder joint 47 is accessible through the aligned opening 50 in

the second body portion **42**.

As can also be seen in the illustrated embodiment, a solder joint **55** is provided between the tin layer **34** of the outer conductor **32** and the first connector body portion **41**. It is this solder joint **55** which provides a good electrical connection, as well as a strong mechanical connection between the cable end and connector. This solder joint **55** is also visible/accessible through the slotted opening **56** formed transversely through the wall of the first body portion **41** in the illustrated embodiment.

The solder joint **55** can be readily formed by first positioning a body of solder, or solder preform, between the outer conductor **32** and the adjacent interior portions of the first connector body portion **41**. Subsequently applied heat will cause the solder to flow, and, upon cooling, complete the connection as will be readily appreciated by those skilled in the art.

Turning now additionally to the schematic manufacturing system **80** of FIG. 7 and the flow chart **58** of FIG. 8, further details of a representative manufacturing operation are now explained. After the start (Block **60**), the inner conductor **26** is input from a supply reel **81** to an extruder **82**. At Block **64**, the extruder **82** extrudes the dielectric layer **30** as will be appreciated by those skilled in the art. Due to the heat of the extruding process, the inner conductor/dielectric layer assembly may pass through a series of cooling tanks, not shown.

A coil of flat aluminum stock is illustratively fed from a supply reel **83** through a series of forming rollers **84** to shape the stock into a tube. The tube may be

continuously butt welded downstream from the rollers 84 at the schematically illustrated welding station 85 to form the aluminum tube 33 (Block 66). Thereafter, at Block 68, the aluminum tube 33 is plated with tin at a  
5 plating station 87. The plating station 87 illustratively includes a series of chemical plating/treatment baths 88 as will be readily appreciated by those of skill in the art. For example, cleaning and rinsing tanks may be provided in some embodiments, in  
10 addition to the plating tank. Other configurations are also contemplated by the present invention. The plating bath may rely on well-known electrochemical plating chemistry as will be readily appreciated by those skilled in the art without requiring further discussion herein.

15 The partially completed cable then illustratively passes through a final extruder 90 which extrudes the outer jacket 36 at Block 70. The jumper coaxial cable 25 is then taken up and stored on a supply reel 91 for use in subsequent assembly steps. More particularly, as shown  
20 in the lower portion of FIG. 7, the jumper coaxial cable 25 from the supply reel 91 may be cut to length at a cutting station or table 93 (Block 72). At Block 74, downstream from the cutting station 93, the solder-on connector 40 is assembled onto the prepared end of the  
25 jumper coaxial cable 25, and heat applied by the schematically illustrated induction heater 95. Accordingly, the solder preform positioned between the outer conductor 32 and adjacent portions of the connector 40 is melted and flows to join these adjacent portions  
30 together as will be readily understood by those skilled in the art.

The solder may comprise conventional tin/lead

alloys, or other low melting temperature materials as will be appreciated by those skilled in the art. The surfaces may also be additionally prepared using flux as will also be appreciated by those skilled in the art. In  
5 yet other embodiments, soldering may be performed by injecting melted solder between adjacent portions of the connector and the outer conductor as will be appreciated by those skilled in the art.

Of course, if two connectors 40 are desired, the  
10 connector assembly and heating operations are repeated. Downstream from the inductive heater 95, final inspection may be performed, before the jumper cable assembly 20 is packaged into containers 96 for shipping at Block 76 before stopping at Block 78.

15 As described above, in some embodiments, it may be preferred to plate the tin onto the aluminum tube; however, in other embodiments of the invention, the flat stock provided for forming the outer conductor, may already be tin-plated. In addition, many modifications  
20 and other embodiments of the invention will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific  
25 embodiments disclosed, and that modifications and embodiments are intended to be included within the scope of the appended claims.